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This report summarizes the effort on the development of accurate and computationally efficient codes for large scale electromagnetic problems with emphasis on three-dimensional monolithic circuits for high-frequency applications. The development is successfully accomplished by:

Code parallelization using Massage Passing Interface (MPI).

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Parallel Electromagnetic Solvers for High Frequency Antenna and Circuit Design

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THE UNIVERSITY OF MICHIGAN

Parallel Electromagnetic Solvers for High Frequency Antenna and Circuit Design

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* *This file includes introduction, project goal, applications of the developed electromagnetic solver, and the details of directories and files in the report.*

1. Introduction

This report summarizes the effort on the development of accurate and computationally efficient codes for large scale electromagnetic problems with emphasis on three-dimensional monolithic circuits for high-frequency applications. The development is successfully accomplished by:

- Code parallelization using Massage Passing Interface (MPI).

In the following, description of CHSSI scalable software project goals and progress summaries for various efforts are provided.

2. Project Goal

High-frequency radar systems for communication, detection and surveillance incorporate MMIC modules which are characterized by high density and substantial geometrical complexity. In most cases these modules are packaged for electrical and/or environmental protection and the resulting 3D structures exhibit a considerable complexity that impedes design and influences electrical performance due to unwanted parasitics. The design of these complex three-dimensional monolithic circuit (MMIC modules) with hundreds of vias and lines interconnecting a large number of active and passive circuit components to a rather large number of radiating elements, has been a problem of critical importance to DoD. The design and characterization of these circuits requires numerical approaches which can fully characterize the excited electromagnetic fields. Among the various techniques, the method of moments has demonstrated superiority in solving radiation problems but it has been hindered by long computational times and is limited, for this reason, to small circuits not exceeding more than a few components and interconnecting lines.

In this study, we have concentrated on the development of codes which have the capability to accelerate numerical computations in electromagnetic problems with large computational domains and/or computationally intensive tasks. Among the existing full-wave methods which have been developed for the solution of EM problems are the Integral Equation Technique (IE) and Finite Element Method (FEM). These methods are numerical techniques which solve Maxwell's Equations in the frequency domain using large computational volumes and intensive numerical calculations which have to be performed repeatedly at all frequency points of interest. In addition to these problems, the numerical solution of Maxwell's Equations results in full (IE case) and huge sparse (FEM case) matrices which further limit applicability of the technique. With regards to

substantially increasing the computational efficiency of these techniques, we concentrate on improving IE with code parallelization and FEM through task parallelization.

The project leverages on existing synergism between DOD and the University of Michigan efforts on large-scale simulations of advanced software systems. The team will concentrate on the development, validation, documentation, visualization, and demonstration of scaleable algorithms for modeling critical DOD problems in high frequency electromagnetic circuits. Technology transfer to the DOD user community is an integral component of the project. In addition, cross-platform portability and software reusability will be emphasized using the Message-Passing Interface (MPI) standard.

In our effort, the developement of scalable softwaresis based on the IE and FEM techniques to sustain the high accuracy capability while, at the same time, solve complex planar circuits including their packages in very short times, allowing for real time simulations. Such softwares can eventually lead to real time design and optimization.

3. Parallelized FEM for MMIC Simulation [1,2,5,6]

The numerical analysis of MMIC using parallel computer becomes powerful especially in FEM-based codes. The frequency parallelization of FEM achieves linearly scaleable performance with the number of processors being used. The frequency parallelization is completed using MPI standards for distributed memory machines such as IBM SP2. The application of frequency parallelized FEM code to microstrip feeding network for patch array antenna is accomplished and its field plot is available by a recently developed post field plotting Matlab file. Parallelization schemes will be further applied to the patch antenna structures including their microstrip feeding network using a hybrid method(MoM/FEM). This work will involve the parallelization of matrix generation for this hybrid method, the parallelization of far field calculation for each array antenna and the development of post-processor files for radiation patterns. The parallelized FEM scheme is also appropriate to the characterization of a microwave/millimeterwave package.

As efficient packaging technologies are emphasized for high frequency and high performance microwave/millimeter-wave circuits, it is very important to provide design rules to avoid unwanted electromagnetic effects of the package on the circuit performance. In this study, the electromagnetic effects of a via fence on a microstrip/stripline and the suppression of higher order modes in the cavity are investigated.

In this study, three different types of via fences are considered: continuous metal filled via fence on both sides of the circuits, short section of a via fence on both sides of the circuits, and via fence cross to the circuits. In each case, the fence is moved between 1h to 4h from the circuit where h is the height between the ground plane and the center conductor of the circuit. As the scattering parameters and radiation loss of the circuits do not vary by more than a few percent over the simulation frequency (10 GHz - 40 GHz),

The goal is to verify the experimental results of mixer circuits under consideration and make some further improvements. In the next step, the harmonic balance code will be integrated into the FEM method and will be parallelized. The direct inclusion of linear passive elements (resistors, capacitiors etc) into FEM code has already been accomplished.

DIRECTORY: /Hybrid/

This file describes the directories and files used in hybrid-method.

- **We define** ***users file*** **as a file users should use (modify or compile) for the simulation.**
- **Notes on file which include frequency information:**
  Frequency information must be written in total of 5 digits number (1 digit above the decimal point and 4 digits under decimal point) in the FEM and MOM input file.
  Example) FEM_MAIN_2.2250GHz.dat2, data_2.2250GHz

Directory : **/Hybrid/Hybrid_kea_FILE**

- The files in this directory is to calculate propagation constants in substrates and writes it in FEM and MOM input file such that it can be used as a slope of basis.

File name	Description
FEM_MAIN_2.2250GHz.dat2	***users file*** FEM input file for sources on slot
data_2.2250GHz	***users file*** MOM input file
Hybrid_dat2.c	***users file*** Main program for calculating propagation constant
Hybrid_dat2.input	***users file*** Input file about frequencies to run for Hybrid_dat2.c
keanew.c my_exit.h complex.h kea_adapgaus.c bisect.c qejyy.c	Library file for Hybrid_dat.2